

Article

Growth, Nutrient Accumulation, and Nutritional Efficiency of a Clonal Eucalyptus Hybrid in Competition with Grasses

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Citation: Maciel, J.C.; Duque, T.S.; Ferreira, E.A.; Zanuncio, J.C.; Plata-Rueda, A.; Silva, V.P.; Silva, D.V.; Fernandes, B.C.C.; Barros Júnior, A.P.; dos Santos, J.B. Growth, Nutrient Accumulation, and Nutritional Efficiency of a Clonal Eucalyptus Hybrid in Competition with Grasses. *Forests* **2022**, *13*, 1157. <https://doi.org/10.3390/f13081157>

Received: 23 May 2022

Accepted: 19 July 2022

Published: 22 July 2022

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Abstract: Invasive grasses reduce resource availability, mainly nutrients in the soil, and the growth of eucalyptus plants. Efficient management to increase productivity depends on understanding levels of weed interference in eucalyptus plantations. The nutritional efficiency of eucalyptus plants in competition has been evaluated by plant tissue analysis. The objective was to evaluate the growth, relative accumulation of nutrients, and nutritional efficiency of the eucalyptus clonal hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*), in competition with *Megathyrsus maximus* cv. BRS zuri, *Urochloa brizantha* cv. marandu, *Urochloa decumbens* cv. basilisk and in the control (eucalyptus plants without weed competition). The experiment was carried out with a completely randomized design, with four treatments and ten replications. The height, stem diameter, number of leaves, leaf area, dry matter of leaves and stem, nutrient content in leaves and uptake, transport, and N, P, and K utilization efficiency of the eucalyptus clonal hybrid were evaluated at 110 days after transplantation. The growth parameters and relative contents of macro and micronutrients in the eucalyptus clonal hybrid were lower in competition with *M. maximus*, *U. brizantha* and *U. decumbens*. The efficiency of N, P, and K uptake and transport by the eucalyptus clonal hybrid was 29.41 and 7.32% lower in competition with *U. decumbens* than in the control treatments, respectively. The efficiency of N, P, and K utilization by eucalypts was 13.73, 9.18, and 22.54% lower in competition with *M. maximus*, *U. brizantha*, and *U. decumbens*, respectively. The reduced growth and nutritional parameters of the eucalyptus clonal hybrid were more evident in competition with *U. decumbens*. Plant tissue analyses efficiently determined the level of competition for nutrients between species. Crop competition with grasses can decrease the efficiency and use of nutrients, which consequently reduces plant development and productivity.

Keywords: clonal eucalyptus; invasive grasses; nutritional efficiency; relative accumulation of nutrients; *Urochloa decumbens*

1. Introduction

Plants of the genus *Eucalyptus* are among the most planted forest species in the world [1], in more than 120 countries in tropical and subtropical regions [2,3]. Eucalyptus

wood is used for a variety of purposes, including fiber production, cellulose, and energy generation [4,5]. Brazilian forest crops are the most productive in the world and are constantly expanding [6].

Techniques such as hybridization and cloning increase the productivity of forest crops [7]. However, competition with weeds can reduce the growth of eucalyptus plants, especially from the initial implantation stage to two years after planting [8]. Weeds in eucalyptus plantations reduce the productivity of this crop [9,10].

The absorption and accumulation of nutrients from the soil by cultivated plants varies according to the degree of competition with weeds, soil water content, differences in growth habits, and nutritional requirements of the species [11]. Moreover, the period of competition for resources between the weed community and the crop also changes the degree of interference [11].

Grasses with rapid tillering reduce the growth of eucalyptus seedlings [12]. *Urochloa brizantha* and *U. decumbens* are more efficient at accumulating biomass and using water than eucalyptus plants at early developmental stages [13]. These grasses are major pests in Brazilian eucalyptus crops [14] with *Megathyrus maximus* among the main species that cause interference in forest plantations [15].

Weed interference in eucalyptus crops warrants study due to the economic relevance of the products and by-products derived from this culture [16]. The composition of invasive communities affects resource availability for tree species [17]. Knowledge about the critical period for interference prevention (PCPI) [18] and changes in growth and competition for resources, such as water and nutrients, are essential to manage forest crops to maximize productivity [17].

Plant species respond to environmental heterogeneity, such as changes in resource availability, presenting phenotypic and physiological changes [19]. Therefore, research regarding the accumulation of nutrients by eucalyptus plants in competition allows us to understand the relationships between species and the effects of nutrient accumulation on physiological and growth parameters [8]. Plant tissue analyses are tools to determine the response to competition for soil resources [20]. The nutritional content of leaves indicates the efficiency of cultivated plants in accumulating nutrients when in competition [21].

The objective was to evaluate the growth, nutrient content, and nutritional efficiency of the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*) competing with the weeds *Megathyrus maximus* cv. BRS zuri, *Urochloa brizantha* cv. Marandu, and *Urochloa decumbens* cv. Basilisk at 110 days after transplanting.

2. Material and Methods

2.1. Study Site and Soil Characteristics

The study was carried out at the JK Campus of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM) in Diamantina, Minas Gerais, Brazil (18°10' S, 43°30' W and altitude 1387 m) in a greenhouse with a minimum temperature of 23 °C and maximum of 34 °C (Figure 1).

The clayey soil used in the experiment was collected at a depth of 0 to 20 cm in the municipality of Curvelo, Minas Gerais, Brazil. Soil analysis was performed at the Viçosa Soil Analysis Laboratory in Viçosa, Minas Gerais, Brazil (Table 1).

The soil was sieved in a 4 mm mesh sieve and fertilized with 32.0 g of ammonium sulfate m^{-3} , 115.2 g single superphosphate m^{-3} , and 92.8 g of potassium chloride m^{-3} , as recommended for planting eucalyptus seedlings in a nursery, in Minas Gerais, Brazil [22]. Nitrogen fertilization was performed according to soil organic matter content.

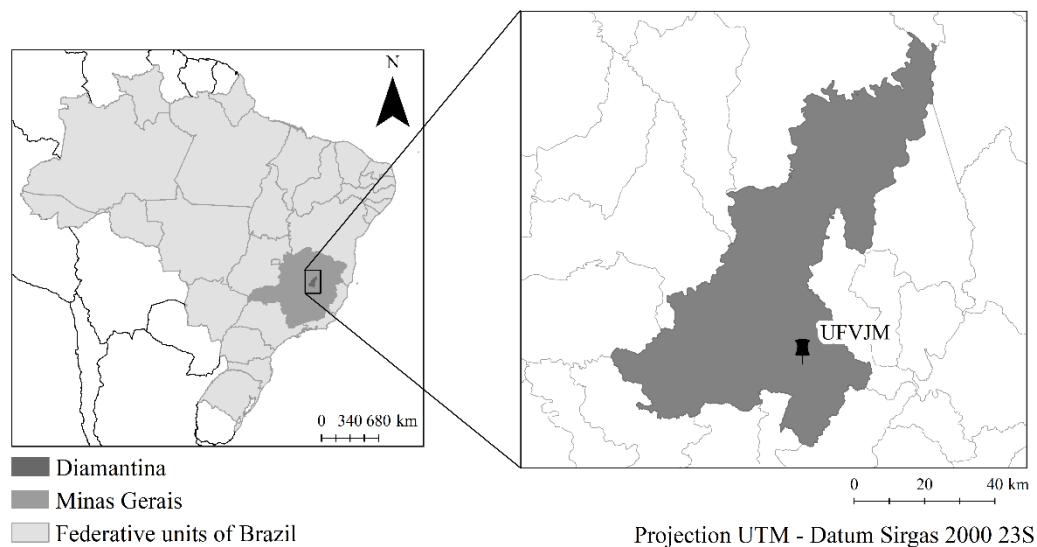


Figure 1. Location of the study site, JK Campus of the Universidade Federal dos Vales do Jequitinhonha and Mucuri (UFVJM) in Diamantina, Minas Gerais, Brazil.

Table 1. Physicochemical characteristics of soil samples used in the cultivation of the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus* in competition with grasses).

pH	P	K	Ca	Mg	Al	H + AL	SB	(t)	T	V	m	MO
(H ₂ O)	mg dm ⁻³					cmolc dm ⁻³				%		dag kg ⁻¹
5.0	0.54	31	0.18	0.13	0.80	4.62	0.39	1.19	5.01	7.8	67.2	1.88
Sand: 6.0% Clay: 69.0% Silt: 25%												

SourSource: Viçosa Soil Analysis Laboratory LTDA. The pH of water with KCl and CaCl ratio 1:2.5; P-K—Mehlich Extractor 1; Ca-Mg-Al—extractor: KCl-1 mol/L; H + Al—calcium acetate extractor 0.5 mol/L—pH 7.0; S—extractor—monocalcium phosphate in acetic acid; SB = sum of exchangeable bases; CTC (t)—effective cation exchange capacity; CTC (T)—cation exchange capacity at pH 7.0; V = base saturation index; m = aluminum saturation Index; Matt. Org. (MO) = C.Org × 1.724—Walkley–Black.

2.2. Experimental Design and Layout

The experiment was carried out in a completely randomized design with four treatments and ten replications, each with one eucalyptus plant competing with *M. maximus*, *U. brizantha*, or *U. decumbens*, in addition to the control (eucalyptus plants without competition).

Commercial seedlings of the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*) and seeds of the weeds *M. maximus*, *U. brizantha*, and *U. decumbens* were used.

The seedlings of the clonal eucalyptus hybrid were placed in a greenhouse for acclimatization one month before transplanting. The experimental units consisted of 7 dm³ polyethylene pots filled with soil and a planted eucalyptus seedling.

In all treatments, the formulated liquid biostimulant (12.3 Mg, 35.7 S, 22.1 Fe and 24.6 g/L Zn) was applied seven days after transplanting the eucalyptus seedlings. According to the treatments, ten seeds of each weed were sown at a depth of 1 to 2 cm per experimental unit, and thinning was performed after emergence, leaving one seedling per pot. Irrigation was daily, maintaining the humidity between 70% to 80% of field capacity.

2.3. Growth Parameter Analysis

The height (from the collar to the insertion of the last leaf), stem diameter (measured with a digital caliper model 1108 at two centimeters above the ground), number of leaves, and leaf area of clonal eucalyptus hybrid plants were evaluated at 110 days after transplantation (DAT). Leaf area was assessed in photographs of the leaf surface of five plants (replications) per treatment, using a graduated ruler for spatial measurement calibration.

The images were processed using the Image-Pro Plus® software (version 4.5.0.29, Media Cybernetics, Inc., Silver Spring, ML, USA).

The eucalyptus plants were collected at 110 DAT, placed in paper bags in an oven with forced air circulation at 65 °C until constant mass, and weighed on a precision scale to determine the dry matter of leaves and stem.

2.4. Analysis of Nutritional Parameters

The dry matter of eucalyptus plants was ground in a Willey mill at the Viçosa Soil Analysis Laboratory of the Federal University of Viçosa, Minas Gerais, Brazil. This process was carried out to determine the levels of macro and micronutrients.

The phosphorus (P) content after nitric–perchloric digestion was determined using the vitamin C method [23], potassium (K) by flame photometry (Saruge and Haag, 1974), sulfur (S) by sulfate turbidimetry [24], calcium (Ca), copper (Cu), magnesium (Mg), manganese (Mn), iron (Fe), and zinc (Zn) by atomic absorption spectrophotometry [23], nitrogen (N) after sulfuric digestion by the Kjeldahl method [25], and boron (B) after digestion by the dry route, by colorimetry with azomethine H [26].

The efficiency in the absorption (EA) of N, P, and K was obtained by the content of these nutrients in the plant (mg)/root dry matter (g) [27], the transport (ET) by the N, P, and K content in the shoot/N, P, and K content in the plant \times 100 [28], and the utilization (EU) by the total dry matter produced² (g)/N, P and K content in the plant (mg) [29].

2.5. Statistical Analysis

Analysis of variance (ANOVA) was performed using the F test and, when significant, the means were compared using the SNK test at 5% probability with the SISVAR statistical program [30].

3. Results

3.1. Growth Parameters

The height, leaf area, and dry matter of leaves and stem of the clonal eucalyptus hybrid were lower when competing with *M. maximus*, *U. brizantha*, and *U. decumbens* (Figure 2).



Figure 2. Height of eucalyptus clonal hybrid I144 (*Eucalyptus urophylla* \times *Eucalyptus grandis*) in competition with grasses at 110 DAT. Control: eucalyptus without competition; EUb: competition with *U. brizantha*; EUD: competition with *U. decumbens*; EMm: competition with *M. maximus*.

The stem diameter of the clonal eucalyptus hybrid was smaller when competing with *U. decumbens*. The number of the eucalyptus clonal hybrid leaves were lower when competing with *M. maximus* and *U. decumbens* (Table 2).

Table 2. Height, stem diameter (mm), number of leaves, leaf area (cm²), leaf dry matter (g) and stem dry matter (g) of the the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*) at 110 DAT.

	Control	EMm	EUb	EUd	CV
Height	100.75 ^{0.82} a	83.95 ^{1.63} b	87.00 ^{0.80} b	86.90 ^{2.42} b	3.91
Stem diameter	10.71 ^{0.14} a	10.31 ^{0.13} a	10.36 ^{0.24} a	9.65 ^{0.20} b	4.05
Number of leaves	398.90 ^{4.62} a	327.30 ^{7.26} c	353.50 ^{2.92} b	309.70 ^{0.13} c	4.15
Leaf area	7374.81 ^{1.95} a	5798.32 ⁴⁴¹ b	5981.73 ²⁶¹ b	5608.97 ²⁴⁶ b	15.38
Leaf dry matter	41.37 ^{0.42} a	33.51 ^{1.04} b	34.40 ^{1.70} b	30.87 ^{2.30} b	9.83
Stem dry matter	32.19 ^{0.31} a	25.10 ^{0.73} b	26.70 ^{2.02} b	23.54 ^{1.42} b	26.71

Control: eucalyptus without competition; EMm: competition with *M. maximus*; EUb: competition with *U. brizantha*; EUd: competition with *U. decumbens*. Means followed by the same letter per line do not differ by the SNK test at 95% probability. CV: coefficient of variation (%), ns: non-significant by the F test at 95% probability. Superscripted values are the standard error of the mean.

3.2. Relative Nutrient Content

The levels of macro and micronutrients (RC) were lower in the leaves of the clonal eucalyptus hybrid competing with *M. maximus* with N (85%), P (88%), K (91%), Zn (97%), Mn (96%), and Cu (94%); with *U. brizantha* of N (96%), P (84%), Cu (94%), and B (97%); and with *U. decumbens* of N (83%), P (96%), Mg (98%), Zn (92%), Fe (92%), Mn (84%), Cu (89%), and B (88%) than in the control (Table 3).

Table 3. Relative content (RC) (%) of the macro and micronutrients in leaves of the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*) at 110 DAT.

Treatments	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
Control	100	100	100	100	100	100	100	100	100	100	100
EMm	85	88	91	103	100	107	97	111	96	94	103
EUb	96	84	101	109	102	117	116	105	102	94	97
EUd	83	96	101	102	98	113	92	92	84	89	88

Control: eucalyptus without competition; EMm: competition with *M. maximus*; EUb: competition with *U. brizantha*; EUd: competition with *U. decumbens*.

3.3. Nutritional Efficiency

The absorption efficiency of the clonal eucalyptus hybrid for N, P, and K was 35.07, 21.58, and 20.17% lower, respectively, when competing with *U. decumbens* (EUd), when compared with the control treatment. The NPK transport efficiency of the eucalyptus clonal hybrid was 7.32% lower in competition with *U. decumbens* (EUd) than the control (Table 4).

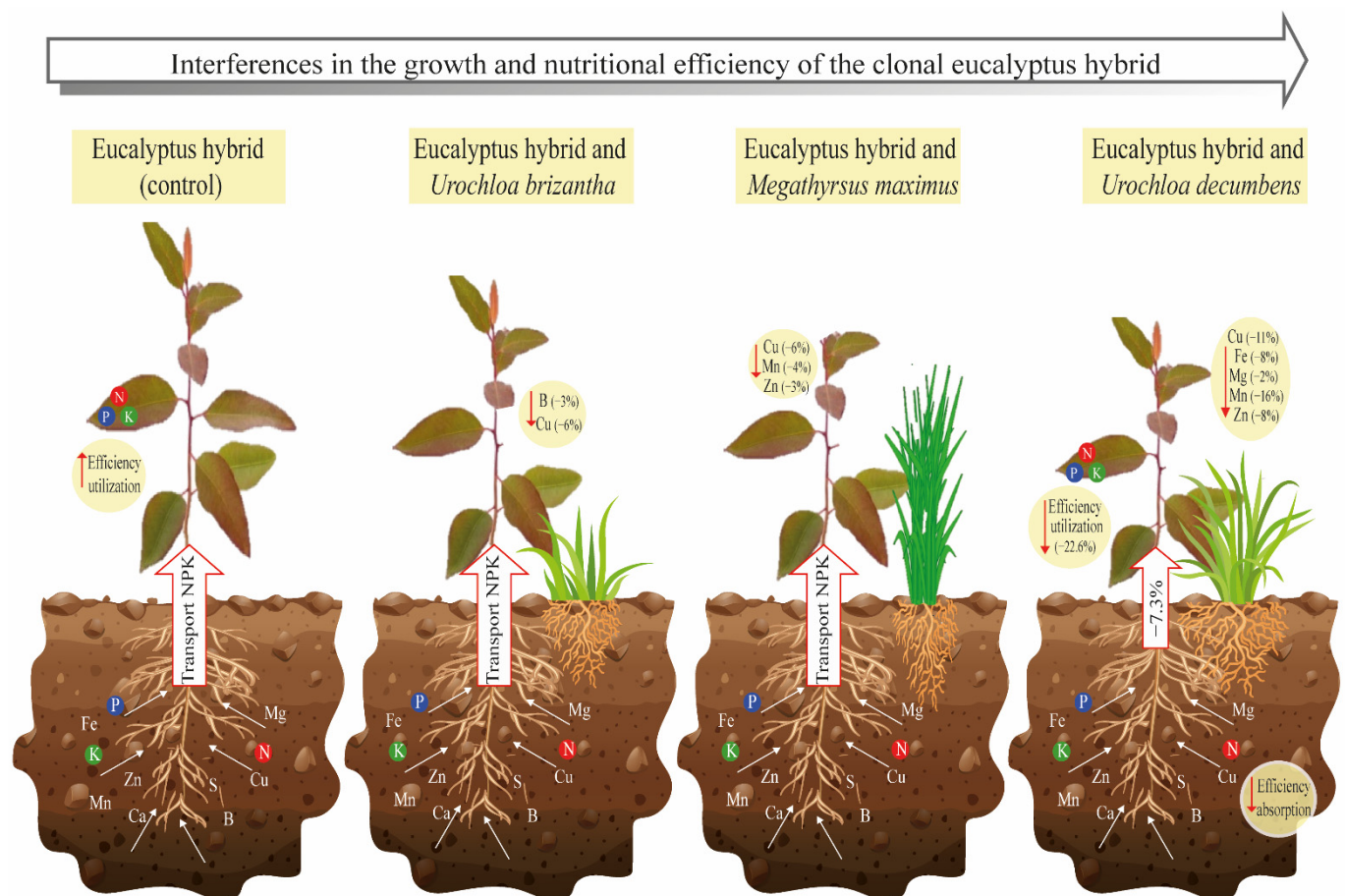
The N, P, and K utilization efficiency of the eucalyptus clonal hybrid reduced in competition with all grasses. The efficiency of N and K utilization was lower in competition with *M. maximus* (EMm), *U. brizantha* (EUb), and *U. decumbens* (EUd), and the P was lower in competition with *U. decumbens* (EUd) (Table 4).

Reductions in the absorption, transport, and utilization of N, P, and K were observed mainly in the eucalyptus hybrid in competition with *U. decumbens*. In addition, the relative content of five micronutrients decreased compared to the control. Limitations in the absorption, transport and use of nutrients reduced all growth parameter values assessed for eucalyptus hybrids in competition with *U. decumbens* (Figure 3).

Table 4. Absorption efficiency (EA), transport (ET), and utilization (EU) of N, P, and K by the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*) at 110 DAT.

Treatments			Control	EMm	EUb	EUD	CV
EA	(mg/g)	N	20.96 ^{0.17} c	30.14 ^{0.78} a	25.04 ^{0.48} b	13.61 ^{0.77} d	6.03
		P	1.39 ^{0.01} b	2.05 ^{0.05} a	1.52 ^{0.03} b	1.09 ^{0.06} c	6.46
		K	11.65 ^{0.09} c	17.85 ^{0.46} a	14.74 ^{0.28} b	9.30 ^{0.53} d	6.36
ET	(%)	NPK	88.45 ^{0.09} a	92.49 ^{0.53} a	90.25 ^{0.41} a	81.97 ^{3.64} b	4.68
EU	(g ² /mg)	N	34.49 ^{0.28} a	30.53 ^{0.79} b	29.14 ^{0.55} b	32.02 ^{1.8} b	7.36
		P	519.49 ^{4.21} a	449.36 ^{11.67} b	480.81 ^{9.15} ab	398.29 ^{22.57} c	6.61
		K	62.03 ^{0.50} a	51.57 ^{1.34} b	49.50 ^{0.94} b	46.86 ^{4.42} b	10.1

Control: eucalyptus without competition; EMm: competition with *Megathyrus maximus*; EUb: competition with *Urochloa brizantha*; EUD: competition with *Urochloa decumbens*. Means followed by the same letter per line do not differ by SNK test at 95% probability. CV: coefficient of variation (%), ns: non-significant by F test at 95% probability. Superscripted values represent the standard error of the mean.

**Figure 3.** Summary of interferences in the growth and nutritional efficiency of the clonal eucalyptus hybrid I144 (*Eucalyptus urophylla* × *Eucalyptus grandis*).

4. Discussion

4.1. Growth Parameters

The lower height, leaf area, number of leaves, and dry matter of leaves and stem of eucalyptus plants in competition with *M. maximus*, *U. brizantha*, and *U. decumbens* are due to the more efficient nutrient extraction and absorption and water use by these weeds. This reduces the availability of these resources at early developmental stages of eucalypts [31]. The fasciculated root system, the higher concentration of root hairs [32,33], and the mutualistic symbiosis with mycorrhizal fungi [34,35] increase the contact surface of the roots and the absorption of water and nutrients by grasses [36,37].

The smaller stem diameter of eucalyptus plants in competition with *U. decumbens* is due to this grass being more competitive in extracting nutrients such as potassium [31,38]. This nutrient is required for the osmotic balance of cells and its availability in the soil is associated with stem diameter growth in eucalyptus clones [39,40]. Therefore, the limitation of uptake by the eucalyptus clonal hybrid reduces cell expansion, cell wall formation, and stem diameter of this plant [41].

4.2. Relative Nutrient Content

The reduction in macro and micronutrient content of eucalyptus plants in competition with *M. maximus* is due to the fact that this grass requires a greater amount of nutrients for shoot growth [42,43] and, with *Urochloa* spp., due to the efficiency of their roots in absorbing nutrients [44]. Moreover, *M. maximus*, *U. brizantha*, and *U. decumbens* consume resources beyond the limiting amount for their growth [45], and the association with mycorrhiza favors this consumption [46–48]. Competition with *M. maximus*, *U. brizantha*, and *U. decumbens* reduced the nutrient supply for the eucalyptus clonal hybrid [36].

4.3. Nutritional Efficiency

The lower efficiency of N, P, and K uptake of the eucalyptus clonal hybrid in competition with *U. decumbens* is due to the root system of the weed developing at large angles, better exploring the soil horizontally [44]. Furthermore, considering the pH range adopted (5.0), *U. decumbens* roots absorb more nutrients than *M. maximus* and *U. brizantha* [49]. Root growth of grasses grown in acidic soils is lower [50], but *U. decumbens* tolerates very low pH values (3.5) and different Al^{3+} concentrations due to changes in the distribution of pectin molecules in the cell wall, favoring stable bonds with Al^{3+} to the detriment of Ca^{2+} [49]. Al^{3+} tolerant species, such as *U. decumbens*, are more efficient than *M. maximus* and *U. brizantha* in capturing nutrients such as N, P, and K [51–53], which, when in competition, limits the uptake by the eucalyptus clonal hybrid.

The lower NPK transport efficiency of eucalyptus plants in competition with *U. Decumbens* is due to the high efficiency of water uptake and use by this grass [54,55]. Limitations in water uptake by eucalyptus cause an induced water deficit [56,57], which restricts nutrient transport [58–60]. Moreover, the lower nutrient uptake by eucalyptus in competition with *U. decumbens* reduces nutritional supply, which limits translocation to the aerial part of the plant [61,62].

Competition with grasses restricted the availability of nutrients for the eucalyptus clonal hybrid [63,64], reducing the efficiency of NPK utilization by this plant. Lower nitrogen uptake and utilization affect cell wall synthesis and organization, causing adaptations in the root system [65,66]. Decreases in phosphorus uptake reduce cell elongation and stop primary root growth [67], while lower potassium uptake causes changes in the regulation of root growth [68]. Thus, competition between eucalyptus and grasses limits nutrient absorption, transport, and use, which generates physiological changes and, consequently, reductions in growth parameters [19,69,70].

5. Conclusions

The growth of the eucalyptus clonal hybrid was lower in competition with *M. maximus*, *U. brizantha*, and *U. decumbens*. The relative content of six, four, and eight macro and micronutrients (CR) in the leaves of the eucalyptus clonal hybrid were lower in competition with *M. maximus*, *U. brizantha*, and *U. decumbens* than in the control, respectively. The eucalyptus clonal hybrid N, P, and K uptake and transport efficiency was lower in competition with *U. decumbens* and the utilization efficiency was reduced in competition with all grasses. The competition of eucalyptus with *U. decumbens* caused a significant decrease in the variables evaluated.

Decreased absorption and accumulation of nutrients such as nitrogen, phosphorus, and potassium, essential for cellular structures and osmotic regulation, leads to reductions in shoot and root growth. The results demonstrate that the initial development of euca-

lyptus (110 days after transplanting) can be compromised due to competition with weeds, which require control before productivity and economic liabilities occur.

Author Contributions: J.C.M.: Formal analysis, investigation, writing—original draft, writing—review & editing. T.S.D.: Formal analysis, investigation, writing—original draft, writing—review & editing. E.A.F.: Conceptualization, methodology, resources, writing—review & editing. J.C.Z.: Resources, writing—original draft, writing—review & editing, supervision. A.P.-R.: Resources, writing—original draft, writing—review & editing, supervision. V.P.S.: Writing—original draft, methodology. D.V.S.: Resources, writing—original draft, writing—review & editing, supervision. B.C.C.F.: Resources, writing—original draft, writing—review & editing, supervision. A.P.B.J.: Resources, writing—original draft, writing—review & editing, supervision. J.B.d.S.: Conceptualization, methodology, resources, writing—original draft, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Funding: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior: 001; Fundação de Amparo à Pesquisa do Estado de Minas Gerais: 001; Conselho Nacional de Desenvolvimento Científico e Tecnológico: 001; Syngenta MAI DAI/UFVJM/CNPq (Process number: 2021).

Data Availability Statement: Not applicable.

Acknowledgments: To the “Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)”, “Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)—Código Financeiro 001” and “Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)”, Syngenta Crop Protection and “Programa Cooperativo sobre Proteção Florestal (PROTEF) do Instituto de Pesquisas e Estudos Florestais (IPEF)” for financial support. Phillip John Villani (University of Melbourne, Australia) revised and corrected the English language used in this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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